

# Observation of $B$ -meson decays to $b_1\pi$ and $b_1K$

B. Aubert,<sup>1</sup> M. Bona,<sup>1</sup> D. Boutigny,<sup>1</sup> Y. Karyotakis,<sup>1</sup> J. P. Lees,<sup>1</sup> V. Poireau,<sup>1</sup> X. Prudent,<sup>1</sup> V. Tisserand,<sup>1</sup>  
A. Zghiche,<sup>1</sup> J. Garra Tico,<sup>2</sup> E. Grauges,<sup>2</sup> L. Lopez,<sup>3</sup> A. Palano,<sup>3</sup> M. Pappagallo,<sup>3</sup> G. Eigen,<sup>4</sup> B. Stugu,<sup>4</sup>  
L. Sun,<sup>4</sup> G. S. Abrams,<sup>5</sup> M. Battaglia,<sup>5</sup> D. N. Brown,<sup>5</sup> J. Button-Shafer,<sup>5</sup> R. N. Cahn,<sup>5</sup> Y. Groyzman,<sup>5</sup>  
R. G. Jacobsen,<sup>5</sup> J. A. Kadyk,<sup>5</sup> L. T. Kerth,<sup>5</sup> Yu. G. Kolomensky,<sup>5</sup> G. Kukartsev,<sup>5</sup> D. Lopes Pegna,<sup>5</sup> G. Lynch,<sup>5</sup>  
L. M. Mir,<sup>5</sup> T. J. Orimoto,<sup>5</sup> I. L. Osipenkov,<sup>5</sup> M. T. Ronan,<sup>5,\*</sup> K. Tackmann,<sup>5</sup> T. Tanabe,<sup>5</sup> W. A. Wenzel,<sup>5</sup>  
P. del Amo Sanchez,<sup>6</sup> C. M. Hawkes,<sup>6</sup> A. T. Watson,<sup>6</sup> T. Held,<sup>7</sup> H. Koch,<sup>7</sup> M. Pelizaeus,<sup>7</sup> T. Schroeder,<sup>7</sup>  
M. Steinke,<sup>7</sup> D. Walker,<sup>8</sup> D. J. Asgeirsson,<sup>9</sup> T. Cuhadar-Donszelmann,<sup>9</sup> B. G. Fulsom,<sup>9</sup> C. Hearty,<sup>9</sup> T. S. Mattison,<sup>9</sup>  
J. A. McKenna,<sup>9</sup> M. Barrett,<sup>10</sup> A. Khan,<sup>10</sup> M. Saleem,<sup>10</sup> L. Teodorescu,<sup>10</sup> V. E. Blinov,<sup>11</sup> A. D. Bukin,<sup>11</sup>  
V. P. Druzhinin,<sup>11</sup> V. B. Golubev,<sup>11</sup> A. P. Onuchin,<sup>11</sup> S. I. Serednyakov,<sup>11</sup> Yu. I. Skovpen,<sup>11</sup> E. P. Solodov,<sup>11</sup>  
K. Yu. Todyshev,<sup>11</sup> M. Bondioli,<sup>12</sup> S. Curry,<sup>12</sup> I. Eschrich,<sup>12</sup> D. Kirkby,<sup>12</sup> A. J. Lankford,<sup>12</sup> P. Lund,<sup>12</sup>  
M. Mandelkern,<sup>12</sup> E. C. Martin,<sup>12</sup> D. P. Stoker,<sup>12</sup> S. Abachi,<sup>13</sup> C. Buchanan,<sup>13</sup> S. D. Foulkes,<sup>14</sup> J. W. Gary,<sup>14</sup>  
F. Liu,<sup>14</sup> O. Long,<sup>14</sup> B. C. Shen,<sup>14</sup> L. Zhang,<sup>14</sup> H. P. Paar,<sup>15</sup> S. Rahatlou,<sup>15</sup> V. Sharma,<sup>15</sup> J. W. Berryhill,<sup>16</sup>  
C. Campagnari,<sup>16</sup> A. Cunha,<sup>16</sup> B. Dahmes,<sup>16</sup> T. M. Hong,<sup>16</sup> D. Kovalskyi,<sup>16</sup> J. D. Richman,<sup>16</sup> T. W. Beck,<sup>17</sup>  
A. M. Eisner,<sup>17</sup> C. J. Flacco,<sup>17</sup> C. A. Heusch,<sup>17</sup> J. Kroseberg,<sup>17</sup> W. S. Lockman,<sup>17</sup> T. Schalk,<sup>17</sup> B. A. Schumm,<sup>17</sup>  
A. Seiden,<sup>17</sup> M. G. Wilson,<sup>17</sup> L. O. Winstrom,<sup>17</sup> E. Chen,<sup>18</sup> C. H. Cheng,<sup>18</sup> F. Fang,<sup>18</sup> D. G. Hitlin,<sup>18</sup> I. Narsky,<sup>18</sup>  
T. Piatenko,<sup>18</sup> F. C. Porter,<sup>18</sup> R. Andreassen,<sup>19</sup> G. Mancinelli,<sup>19</sup> B. T. Meadows,<sup>19</sup> K. Mishra,<sup>19</sup> M. D. Sokoloff,<sup>19</sup>  
F. Blanc,<sup>20</sup> P. C. Bloom,<sup>20</sup> S. Chen,<sup>20</sup> W. T. Ford,<sup>20</sup> J. F. Hirschauer,<sup>20</sup> A. Kreisel,<sup>20</sup> M. Nagel,<sup>20</sup> U. Nauenberg,<sup>20</sup>  
A. Olivas,<sup>20</sup> J. G. Smith,<sup>20</sup> K. A. Ulmer,<sup>20</sup> S. R. Wagner,<sup>20</sup> J. Zhang,<sup>20</sup> A. M. Gabareen,<sup>21</sup> A. Soffer,<sup>21,†</sup>  
W. H. Toki,<sup>21</sup> R. J. Wilson,<sup>21</sup> F. Winklmeier,<sup>21</sup> D. D. Altenburg,<sup>22</sup> E. Feltresi,<sup>22</sup> A. Hauke,<sup>22</sup> H. Jasper,<sup>22</sup>  
J. Merkel,<sup>22</sup> A. Petzold,<sup>22</sup> B. Spaan,<sup>22</sup> K. Wacker,<sup>22</sup> V. Klose,<sup>23</sup> M. J. Kobel,<sup>23</sup> H. M. Lacker,<sup>23</sup> W. F. Mader,<sup>23</sup>  
R. Nogowski,<sup>23</sup> J. Schubert,<sup>23</sup> K. R. Schubert,<sup>23</sup> R. Schwierz,<sup>23</sup> J. E. Sundermann,<sup>23</sup> A. Volk,<sup>23</sup> D. Bernard,<sup>24</sup>  
G. R. Bonneaud,<sup>24</sup> E. Latour,<sup>24</sup> V. Lombardo,<sup>24</sup> Ch. Thiebaut,<sup>24</sup> M. Verderi,<sup>24</sup> P. J. Clark,<sup>25</sup> W. Gradl,<sup>25</sup>  
F. Muheim,<sup>25</sup> S. Playfer,<sup>25</sup> A. I. Robertson,<sup>25</sup> J. E. Watson,<sup>25</sup> Y. Xie,<sup>25</sup> M. Andreotti,<sup>26</sup> D. Bettoni,<sup>26</sup> C. Bozzi,<sup>26</sup>  
R. Calabrese,<sup>26</sup> A. Cecchi,<sup>26</sup> G. Cibinetto,<sup>26</sup> P. Franchini,<sup>26</sup> E. Luppi,<sup>26</sup> M. Negrini,<sup>26</sup> A. Petrella,<sup>26</sup> L. Piemontese,<sup>26</sup>  
E. Prencipe,<sup>26</sup> V. Santoro,<sup>26</sup> F. Anulli,<sup>27</sup> R. Baldini-Ferrolì,<sup>27</sup> A. Calcaterra,<sup>27</sup> R. de Sangro,<sup>27</sup> G. Finocchiaro,<sup>27</sup>  
S. Pacetti,<sup>27</sup> P. Patteri,<sup>27</sup> I. M. Peruzzi,<sup>27,‡</sup> M. Piccolo,<sup>27</sup> M. Rama,<sup>27</sup> A. Zallo,<sup>27</sup> A. Buzzo,<sup>28</sup> R. Contri,<sup>28</sup>  
M. Lo Vetere,<sup>28</sup> M. M. Macri,<sup>28</sup> M. R. Monge,<sup>28</sup> S. Passaggio,<sup>28</sup> C. Patrignani,<sup>28</sup> E. Robutti,<sup>28</sup> A. Santroni,<sup>28</sup>  
S. Tosi,<sup>28</sup> K. S. Chaisanguanthum,<sup>29</sup> M. Morii,<sup>29</sup> J. Wu,<sup>29</sup> R. S. Dubitzky,<sup>30</sup> J. Marks,<sup>30</sup> S. Schenk,<sup>30</sup> U. Uwer,<sup>30</sup>  
D. J. Bard,<sup>31</sup> P. D. Dauncey,<sup>31</sup> R. L. Flack,<sup>31</sup> J. A. Nash,<sup>31</sup> W. Panduro Vazquez,<sup>31</sup> M. Tibbetts,<sup>31</sup> P. K. Behera,<sup>32</sup>  
X. Chai,<sup>32</sup> M. J. Charles,<sup>32</sup> U. Mallik,<sup>32</sup> V. Ziegler,<sup>32</sup> J. Cochran,<sup>33</sup> H. B. Crawley,<sup>33</sup> L. Dong,<sup>33</sup> V. Eyges,<sup>33</sup>  
W. T. Meyer,<sup>33</sup> S. Prell,<sup>33</sup> E. I. Rosenberg,<sup>33</sup> A. E. Rubin,<sup>33</sup> Y. Y. Gao,<sup>34</sup> A. V. Gritsan,<sup>34</sup> Z. J. Guo,<sup>34</sup> C. K. Lae,<sup>34</sup>  
A. G. Denig,<sup>35</sup> M. Fritsch,<sup>35</sup> G. Schott,<sup>35</sup> N. Arnaud,<sup>36</sup> J. Béguilleux,<sup>36</sup> A. D'Orazio,<sup>36</sup> M. Davier,<sup>36</sup> G. Grosdidier,<sup>36</sup>  
A. Höcker,<sup>36</sup> V. Lepeltier,<sup>36</sup> F. Le Diberder,<sup>36</sup> A. M. Lutz,<sup>36</sup> S. Pruvot,<sup>36</sup> S. Rodier,<sup>36</sup> P. Roudeau,<sup>36</sup> M. H. Schune,<sup>36</sup>  
J. Serrano,<sup>36</sup> V. Sordini,<sup>36</sup> A. Stocchi,<sup>36</sup> W. F. Wang,<sup>36</sup> G. Wormser,<sup>36</sup> D. J. Lange,<sup>37</sup> D. M. Wright,<sup>37</sup> I. Bingham,<sup>38</sup>  
J. P. Burke,<sup>38</sup> C. A. Chavez,<sup>38</sup> I. J. Forster,<sup>38</sup> J. R. Fry,<sup>38</sup> E. Gabathuler,<sup>38</sup> R. Gamet,<sup>38</sup> D. E. Hutchcroft,<sup>38</sup>  
D. J. Payne,<sup>38</sup> K. C. Schofield,<sup>38</sup> C. Touramanis,<sup>38</sup> A. J. Bevan,<sup>39</sup> K. A. George,<sup>39</sup> F. Di Lodovico,<sup>39</sup> W. Menges,<sup>39</sup>  
R. Sacco,<sup>39</sup> G. Cowan,<sup>40</sup> H. U. Flaecher,<sup>40</sup> D. A. Hopkins,<sup>40</sup> S. Paramesvaran,<sup>40</sup> F. Salvatore,<sup>40</sup> A. C. Wren,<sup>40</sup>  
D. N. Brown,<sup>41</sup> C. L. Davis,<sup>41</sup> J. Allison,<sup>42</sup> N. R. Barlow,<sup>42</sup> R. J. Barlow,<sup>42</sup> Y. M. Chia,<sup>42</sup> C. L. Edgar,<sup>42</sup>  
G. D. Lafferty,<sup>42</sup> T. J. West,<sup>42</sup> J. I. Yi,<sup>42</sup> J. Anderson,<sup>43</sup> C. Chen,<sup>43</sup> A. Jawahery,<sup>43</sup> D. A. Roberts,<sup>43</sup> G. Simi,<sup>43</sup>  
J. M. Tuggle,<sup>43</sup> G. Blaylock,<sup>44</sup> C. Dallapiccola,<sup>44</sup> S. S. Hertzbach,<sup>44</sup> X. Li,<sup>44</sup> T. B. Moore,<sup>44</sup> E. Salvati,<sup>44</sup>  
S. Saremi,<sup>44</sup> R. Cowan,<sup>45</sup> D. Dujmic,<sup>45</sup> P. H. Fisher,<sup>45</sup> K. Koeneke,<sup>45</sup> G. Sciolla,<sup>45</sup> S. J. Sekula,<sup>45</sup> M. Spitznagel,<sup>45</sup>  
F. Taylor,<sup>45</sup> R. K. Yamamoto,<sup>45</sup> M. Zhao,<sup>45</sup> Y. Zheng,<sup>45</sup> S. E. Mclachlin,<sup>46,\*</sup> P. M. Patel,<sup>46</sup> S. H. Robertson,<sup>46</sup>  
A. Lazzaro,<sup>47</sup> F. Palombo,<sup>47</sup> J. M. Bauer,<sup>48</sup> L. Cremaldi,<sup>48</sup> V. Eschenburg,<sup>48</sup> R. Godang,<sup>48</sup> R. Kroeger,<sup>48</sup>  
D. A. Sanders,<sup>48</sup> D. J. Summers,<sup>48</sup> H. W. Zhao,<sup>48</sup> S. Brunet,<sup>49</sup> D. Côté,<sup>49</sup> M. Simard,<sup>49</sup> P. Taras,<sup>49</sup> F. B. Viaud,<sup>49</sup>  
H. Nicholson,<sup>50</sup> G. De Nardo,<sup>51</sup> F. Fabozzi,<sup>51,§</sup> L. Lista,<sup>51</sup> D. Monorchio,<sup>51</sup> C. Sciacca,<sup>51</sup> M. A. Baak,<sup>52</sup> G. Raven,<sup>52</sup>  
H. L. Snoek,<sup>52</sup> C. P. Jessop,<sup>53</sup> K. J. Knoepfel,<sup>53</sup> J. M. LoSecco,<sup>53</sup> G. Benelli,<sup>54</sup> L. A. Corwin,<sup>54</sup> K. Honscheid,<sup>54</sup>

H. Kagan,<sup>54</sup> R. Kass,<sup>54</sup> J. P. Morris,<sup>54</sup> A. M. Rahimi,<sup>54</sup> J. J. Regensburger,<sup>54</sup> Q. K. Wong,<sup>54</sup> N. L. Blount,<sup>55</sup> J. Brau,<sup>55</sup> R. Frey,<sup>55</sup> O. Igonkina,<sup>55</sup> J. A. Kolb,<sup>55</sup> M. Lu,<sup>55</sup> R. Rahmat,<sup>55</sup> N. B. Sinev,<sup>55</sup> D. Strom,<sup>55</sup> J. Strube,<sup>55</sup> E. Torrence,<sup>55</sup> N. Gagliardi,<sup>56</sup> A. Gaz,<sup>56</sup> M. Margoni,<sup>56</sup> M. Morandin,<sup>56</sup> A. Pompili,<sup>56</sup> M. Posocco,<sup>56</sup> M. Rotondo,<sup>56</sup> F. Simonetto,<sup>56</sup> R. Stroili,<sup>56</sup> C. Voci,<sup>56</sup> E. Ben-Haim,<sup>57</sup> H. Briand,<sup>57</sup> G. Calderini,<sup>57</sup> J. Chauveau,<sup>57</sup> P. David,<sup>57</sup> L. Del Buono,<sup>57</sup> Ch. de la Vaissière,<sup>57</sup> O. Hamon,<sup>57</sup> Ph. Leruste,<sup>57</sup> J. Malclès,<sup>57</sup> J. Ocariz,<sup>57</sup> A. Perez,<sup>57</sup> J. Prendki,<sup>57</sup> L. Gladney,<sup>58</sup> M. Biasini,<sup>59</sup> R. Covarelli,<sup>59</sup> E. Manoni,<sup>59</sup> C. Angelini,<sup>60</sup> G. Batignani,<sup>60</sup> S. Bettarini,<sup>60</sup> M. Carpinelli,<sup>60</sup> R. Cenci,<sup>60</sup> A. Cervelli,<sup>60</sup> F. Forti,<sup>60</sup> M. A. Giorgi,<sup>60</sup> A. Lusiani,<sup>60</sup> G. Marchiori,<sup>60</sup> M. A. Mazur,<sup>60</sup> M. Morganti,<sup>60</sup> N. Neri,<sup>60</sup> E. Paoloni,<sup>60</sup> G. Rizzo,<sup>60</sup> J. J. Walsh,<sup>60</sup> M. Haire,<sup>61</sup> J. Biesiada,<sup>62</sup> P. Elmer,<sup>62</sup> Y. P. Lau,<sup>62</sup> C. Lu,<sup>62</sup> J. Olsen,<sup>62</sup> A. J. S. Smith,<sup>62</sup> A. V. Telnov,<sup>62</sup> E. Baracchini,<sup>63</sup> F. Bellini,<sup>63</sup> G. Cavoto,<sup>63</sup> D. del Re,<sup>63</sup> E. Di Marco,<sup>63</sup> R. Faccini,<sup>63</sup> F. Ferrarotto,<sup>63</sup> F. Ferroni,<sup>63</sup> M. Gaspero,<sup>63</sup> P. D. Jackson,<sup>63</sup> L. Li Gioi,<sup>63</sup> M. A. Mazzoni,<sup>63</sup> S. Morganti,<sup>63</sup> G. Piredda,<sup>63</sup> F. Polci,<sup>63</sup> F. Renga,<sup>63</sup> C. Voena,<sup>63</sup> M. Ebert,<sup>64</sup> T. Hartmann,<sup>64</sup> H. Schröder,<sup>64</sup> R. Waldi,<sup>64</sup> T. Adye,<sup>65</sup> G. Castelli,<sup>65</sup> B. Franek,<sup>65</sup> E. O. Olaiya,<sup>65</sup> S. Ricciardi,<sup>65</sup> W. Roethel,<sup>65</sup> F. F. Wilson,<sup>65</sup> S. Emery,<sup>66</sup> M. Escalier,<sup>66</sup> A. Gaidot,<sup>66</sup> S. F. Ganzhur,<sup>66</sup> G. Hamel de Monchenault,<sup>66</sup> W. Kozanecki,<sup>66</sup> G. Vasseur,<sup>66</sup> Ch. Yèche,<sup>66</sup> M. Zito,<sup>66</sup> X. R. Chen,<sup>67</sup> H. Liu,<sup>67</sup> W. Park,<sup>67</sup> M. V. Purohit,<sup>67</sup> J. R. Wilson,<sup>67</sup> M. T. Allen,<sup>68</sup> D. Aston,<sup>68</sup> R. Bartoldus,<sup>68</sup> P. Bechtle,<sup>68</sup> N. Berger,<sup>68</sup> R. Claus,<sup>68</sup> J. P. Coleman,<sup>68</sup> M. R. Convery,<sup>68</sup> J. C. Dingfelder,<sup>68</sup> J. Dorfan,<sup>68</sup> G. P. Dubois-Felsmann,<sup>68</sup> W. Dunwoodie,<sup>68</sup> R. C. Field,<sup>68</sup> T. Glanzman,<sup>68</sup> S. J. Gowdy,<sup>68</sup> M. T. Graham,<sup>68</sup> P. Grenier,<sup>68</sup> C. Hast,<sup>68</sup> T. Hryn'ova,<sup>68</sup> W. R. Innes,<sup>68</sup> J. Kaminski,<sup>68</sup> M. H. Kelsey,<sup>68</sup> H. Kim,<sup>68</sup> P. Kim,<sup>68</sup> M. L. Kocian,<sup>68</sup> D. W. G. S. Leith,<sup>68</sup> S. Li,<sup>68</sup> S. Luitz,<sup>68</sup> V. Luth,<sup>68</sup> H. L. Lynch,<sup>68</sup> D. B. MacFarlane,<sup>68</sup> H. Marsiske,<sup>68</sup> R. Messner,<sup>68</sup> D. R. Muller,<sup>68</sup> C. P. O'Grady,<sup>68</sup> I. Ofte,<sup>68</sup> A. Perazzo,<sup>68</sup> M. Perl,<sup>68</sup> T. Pulliam,<sup>68</sup> B. N. Ratcliff,<sup>68</sup> A. Roodman,<sup>68</sup> A. A. Salnikov,<sup>68</sup> R. H. Schindler,<sup>68</sup> J. Schwiening,<sup>68</sup> A. Snyder,<sup>68</sup> J. Stelzer,<sup>68</sup> D. Su,<sup>68</sup> M. K. Sullivan,<sup>68</sup> K. Suzuki,<sup>68</sup> S. K. Swain,<sup>68</sup> J. M. Thompson,<sup>68</sup> J. Va'vra,<sup>68</sup> N. van Bakel,<sup>68</sup> A. P. Wagner,<sup>68</sup> M. Weaver,<sup>68</sup> W. J. Wisniewski,<sup>68</sup> M. Wittgen,<sup>68</sup> D. H. Wright,<sup>68</sup> A. K. Yarritu,<sup>68</sup> K. Yi,<sup>68</sup> C. C. Young,<sup>68</sup> P. R. Burchat,<sup>69</sup> A. J. Edwards,<sup>69</sup> S. A. Majewski,<sup>69</sup> B. A. Petersen,<sup>69</sup> L. Wilden,<sup>69</sup> S. Ahmed,<sup>70</sup> M. S. Alam,<sup>70</sup> R. Bula,<sup>70</sup> J. A. Ernst,<sup>70</sup> V. Jain,<sup>70</sup> B. Pan,<sup>70</sup> M. A. Saeed,<sup>70</sup> F. R. Wappler,<sup>70</sup> S. B. Zain,<sup>70</sup> M. Krishnamurthy,<sup>71</sup> S. M. Spanier,<sup>71</sup> R. Eckmann,<sup>72</sup> J. L. Ritchie,<sup>72</sup> A. M. Ruland,<sup>72</sup> C. J. Schilling,<sup>72</sup> R. F. Schwitters,<sup>72</sup> J. M. Izen,<sup>73</sup> X. C. Lou,<sup>73</sup> S. Ye,<sup>73</sup> F. Bianchi,<sup>74</sup> F. Gallo,<sup>74</sup> D. Gamba,<sup>74</sup> M. Pelliccioni,<sup>74</sup> M. Bomben,<sup>75</sup> L. Bosisio,<sup>75</sup> C. Cartaro,<sup>75</sup> F. Cossutti,<sup>75</sup> G. Della Ricca,<sup>75</sup> L. Lancieri,<sup>75</sup> L. Vitale,<sup>75</sup> V. Azzolini,<sup>76</sup> N. Lopez-March,<sup>76</sup> F. Martinez-Vidal,<sup>76</sup> D. A. Milanes,<sup>76</sup> A. Oyanguren,<sup>76</sup> J. Albert,<sup>77</sup> Sw. Banerjee,<sup>77</sup> B. Bhuyan,<sup>77</sup> K. Hamano,<sup>77</sup> R. Kowalewski,<sup>77</sup> I. M. Nugent,<sup>77</sup> J. M. Roney,<sup>77</sup> R. J. Sobie,<sup>77</sup> P. F. Harrison,<sup>78</sup> J. Ilic,<sup>78</sup> T. E. Latham,<sup>78</sup> G. B. Mohanty,<sup>78</sup> H. R. Band,<sup>79</sup> X. Chen,<sup>79</sup> S. Dasu,<sup>79</sup> K. T. Flood,<sup>79</sup> J. J. Hollar,<sup>79</sup> P. E. Kutter,<sup>79</sup> Y. Pan,<sup>79</sup> M. Pierini,<sup>79</sup> R. Prepost,<sup>79</sup> S. L. Wu,<sup>79</sup> and H. Neal<sup>80</sup>

(The BABAR Collaboration)

<sup>1</sup>Laboratoire de Physique des Particules, IN2P3/CNRS et Université de Savoie, F-74941 Annecy-Le-Vieux, France

<sup>2</sup>Universitat de Barcelona, Facultat de Física, Departament ECM, E-08028 Barcelona, Spain

<sup>3</sup>Università di Bari, Dipartimento di Fisica and INFN, I-70126 Bari, Italy

<sup>4</sup>University of Bergen, Institute of Physics, N-5007 Bergen, Norway

<sup>5</sup>Lawrence Berkeley National Laboratory and University of California, Berkeley, California 94720, USA

<sup>6</sup>University of Birmingham, Birmingham, B15 2TT, United Kingdom

<sup>7</sup>Ruhr Universität Bochum, Institut für Experimentalphysik 1, D-44780 Bochum, Germany

<sup>8</sup>University of Bristol, Bristol BS8 1TL, United Kingdom

<sup>9</sup>University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z1

<sup>10</sup>Brunel University, Uxbridge, Middlesex UB8 3PH, United Kingdom

<sup>11</sup>Budker Institute of Nuclear Physics, Novosibirsk 630090, Russia

<sup>12</sup>University of California at Irvine, Irvine, California 92697, USA

<sup>13</sup>University of California at Los Angeles, Los Angeles, California 90024, USA

<sup>14</sup>University of California at Riverside, Riverside, California 92521, USA

<sup>15</sup>University of California at San Diego, La Jolla, California 92093, USA

<sup>16</sup>University of California at Santa Barbara, Santa Barbara, California 93106, USA

<sup>17</sup>University of California at Santa Cruz, Institute for Particle Physics, Santa Cruz, California 95064, USA

<sup>18</sup>California Institute of Technology, Pasadena, California 91125, USA

<sup>19</sup>University of Cincinnati, Cincinnati, Ohio 45221, USA

<sup>20</sup>University of Colorado, Boulder, Colorado 80309, USA

<sup>21</sup>Colorado State University, Fort Collins, Colorado 80523, USA

<sup>22</sup>Universität Dortmund, Institut für Physik, D-44221 Dortmund, Germany

<sup>23</sup>Technische Universität Dresden, Institut für Kern- und Teilchenphysik, D-01062 Dresden, Germany

<sup>24</sup>Laboratoire Leprince-Ringuet, CNRS/IN2P3, Ecole Polytechnique, F-91128 Palaiseau, France

- <sup>25</sup>University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom
- <sup>26</sup>Università di Ferrara, Dipartimento di Fisica and INFN, I-44100 Ferrara, Italy
- <sup>27</sup>Laboratori Nazionali di Frascati dell'INFN, I-00044 Frascati, Italy
- <sup>28</sup>Università di Genova, Dipartimento di Fisica and INFN, I-16146 Genova, Italy
- <sup>29</sup>Harvard University, Cambridge, Massachusetts 02138, USA
- <sup>30</sup>Universität Heidelberg, Physikalisches Institut, Philosophenweg 12, D-69120 Heidelberg, Germany
- <sup>31</sup>Imperial College London, London, SW7 2AZ, United Kingdom
- <sup>32</sup>University of Iowa, Iowa City, Iowa 52242, USA
- <sup>33</sup>Iowa State University, Ames, Iowa 50011-3160, USA
- <sup>34</sup>Johns Hopkins University, Baltimore, Maryland 21218, USA
- <sup>35</sup>Universität Karlsruhe, Institut für Experimentelle Kernphysik, D-76021 Karlsruhe, Germany
- <sup>36</sup>Laboratoire de l'Accélérateur Linéaire, IN2P3/CNRS et Université Paris-Sud 11, Centre Scientifique d'Orsay, B. P. 34, F-91898 ORSAY Cedex, France
- <sup>37</sup>Lawrence Livermore National Laboratory, Livermore, California 94550, USA
- <sup>38</sup>University of Liverpool, Liverpool L69 7ZE, United Kingdom
- <sup>39</sup>Queen Mary, University of London, E1 4NS, United Kingdom
- <sup>40</sup>University of London, Royal Holloway and Bedford New College, Egham, Surrey TW20 0EX, United Kingdom
- <sup>41</sup>University of Louisville, Louisville, Kentucky 40292, USA
- <sup>42</sup>University of Manchester, Manchester M13 9PL, United Kingdom
- <sup>43</sup>University of Maryland, College Park, Maryland 20742, USA
- <sup>44</sup>University of Massachusetts, Amherst, Massachusetts 01003, USA
- <sup>45</sup>Massachusetts Institute of Technology, Laboratory for Nuclear Science, Cambridge, Massachusetts 02139, USA
- <sup>46</sup>McGill University, Montréal, Québec, Canada H3A 2T8
- <sup>47</sup>Università di Milano, Dipartimento di Fisica and INFN, I-20133 Milano, Italy
- <sup>48</sup>University of Mississippi, University, Mississippi 38677, USA
- <sup>49</sup>Université de Montréal, Physique des Particules, Montréal, Québec, Canada H3C 3J7
- <sup>50</sup>Mount Holyoke College, South Hadley, Massachusetts 01075, USA
- <sup>51</sup>Università di Napoli Federico II, Dipartimento di Scienze Fisiche and INFN, I-80126, Napoli, Italy
- <sup>52</sup>NIKHEF, National Institute for Nuclear Physics and High Energy Physics, NL-1009 DB Amsterdam, The Netherlands
- <sup>53</sup>University of Notre Dame, Notre Dame, Indiana 46556, USA
- <sup>54</sup>Ohio State University, Columbus, Ohio 43210, USA
- <sup>55</sup>University of Oregon, Eugene, Oregon 97403, USA
- <sup>56</sup>Università di Padova, Dipartimento di Fisica and INFN, I-35131 Padova, Italy
- <sup>57</sup>Laboratoire de Physique Nucléaire et de Hautes Energies, IN2P3/CNRS, Université Pierre et Marie Curie-Paris6, Université Denis Diderot-Paris7, F-75252 Paris, France
- <sup>58</sup>University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA
- <sup>59</sup>Università di Perugia, Dipartimento di Fisica and INFN, I-06100 Perugia, Italy
- <sup>60</sup>Università di Pisa, Dipartimento di Fisica, Scuola Normale Superiore and INFN, I-56127 Pisa, Italy
- <sup>61</sup>Prairie View A&M University, Prairie View, Texas 77446, USA
- <sup>62</sup>Princeton University, Princeton, New Jersey 08544, USA
- <sup>63</sup>Università di Roma La Sapienza, Dipartimento di Fisica and INFN, I-00185 Roma, Italy
- <sup>64</sup>Universität Rostock, D-18051 Rostock, Germany
- <sup>65</sup>Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, United Kingdom
- <sup>66</sup>DSM/Dapnia, CEA/Saclay, F-91191 Gif-sur-Yvette, France
- <sup>67</sup>University of South Carolina, Columbia, South Carolina 29208, USA
- <sup>68</sup>Stanford Linear Accelerator Center, Stanford, California 94309, USA
- <sup>69</sup>Stanford University, Stanford, California 94305-4060, USA
- <sup>70</sup>State University of New York, Albany, New York 12222, USA
- <sup>71</sup>University of Tennessee, Knoxville, Tennessee 37996, USA
- <sup>72</sup>University of Texas at Austin, Austin, Texas 78712, USA
- <sup>73</sup>University of Texas at Dallas, Richardson, Texas 75083, USA
- <sup>74</sup>Università di Torino, Dipartimento di Fisica Sperimentale and INFN, I-10125 Torino, Italy
- <sup>75</sup>Università di Trieste, Dipartimento di Fisica and INFN, I-34127 Trieste, Italy
- <sup>76</sup>IFIC, Universitat de Valencia-CSIC, E-46071 Valencia, Spain
- <sup>77</sup>University of Victoria, Victoria, British Columbia, Canada V8W 3P6
- <sup>78</sup>Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom
- <sup>79</sup>University of Wisconsin, Madison, Wisconsin 53706, USA
- <sup>80</sup>Yale University, New Haven, Connecticut 06511, USA
- (Dated: April 1, 2008)

We present the results of searches for decays of  $B$  mesons to final states with a  $b_1$  meson and a charged pion or kaon. The data, collected with the BABAR detector at the Stanford Linear Accelerator Center, represent 382 million  $B\bar{B}$  pairs produced in  $e^+e^-$  annihilation. The results for

the branching fractions are, in units of  $10^{-6}$ ,  $\mathcal{B}(B^+ \rightarrow b_1^0 \pi^+) = 6.7 \pm 1.7 \pm 1.0$  ( $4.0\sigma$ ),  $\mathcal{B}(B^+ \rightarrow b_1^0 K^+) = 9.1 \pm 1.7 \pm 1.0$  ( $5.3\sigma$ ),  $\mathcal{B}(B^0 \rightarrow b_1^\mp \pi^\pm) = 10.9 \pm 1.2 \pm 0.9$  ( $8.9\sigma$ ), and  $\mathcal{B}(B^0 \rightarrow b_1^\mp K^\pm) = 7.4 \pm 1.0 \pm 1.0$  ( $6.1\sigma$ ), with the assumption that  $\mathcal{B}(b_1 \rightarrow \omega \pi) = 1$ . We also measure charge and flavor asymmetries  $\mathcal{A}_{ch}(B^+ \rightarrow b_1^0 \pi^+) = 0.05 \pm 0.16 \pm 0.02$ ,  $\mathcal{A}_{ch}(B^+ \rightarrow b_1^0 K^+) = -0.46 \pm 0.20 \pm 0.02$ ,  $\mathcal{A}_{ch}(B^0 \rightarrow b_1^\mp \pi^\pm) = -0.05 \pm 0.10 \pm 0.02$ ,  $C(B^0 \rightarrow b_1^\mp \pi^\pm) = -0.22 \pm 0.23 \pm 0.05$ ,  $\Delta C(B^0 \rightarrow b_1^\mp \pi^\pm) = -1.04 \pm 0.23 \pm 0.08$ , and  $\mathcal{A}_{ch}(B^0 \rightarrow b_1^\mp K^\pm) = -0.07 \pm 0.12 \pm 0.02$ . The first error quoted is statistical, the second systematic, and for the branching fractions, the significance is given in parentheses.

PACS numbers: 13.25.Hw, 12.15.Hh, 11.30.Er

Recent searches for decays of  $B$  mesons to final states with an axial-vector meson and a pion have revealed modes with rather large branching fractions, e.g.,  $\mathcal{B}(B^0 \rightarrow a_1^\mp \pi^\pm) = (33.2 \pm 3.8 \pm 3.0) \times 10^{-6}$  [1]. Here we search for related modes with a  $b_1^0$  or a  $b_1^\mp$  meson plus a  $\pi^+$  or  $K^+$  [2], in a sample of  $(381.8 \pm 4.2) \times 10^6$   $B\bar{B}$  pairs produced by  $e^+e^-$  annihilation at the  $\Upsilon(4S)$  resonance (center-of-mass energy  $\sqrt{s} = 10.58$  GeV). The integrated luminosity is  $346 \text{ fb}^{-1}$ .

The mass and width of the  $b_1$  are  $1229.5 \pm 3.2$  MeV and  $142 \pm 9$  MeV, respectively, and the dominant decay is to  $\omega \pi$  [3]. In the quark model the  $b_1$  is the  $I^G = 1^+$  member of the  $J^{PC} = 1^{+-}$ ,  $^1P_1$  nonet, whereas the  $a_1$  is the  $I^G = 1^-$  state in the  $J^{PC} = 1^{++}$ ,  $^3P_1$  nonet. The available theoretical estimates of the branching fractions of  $B$  mesons to  $b_1 \pi$  and  $b_1 K$  come from calculations based on naive factorization [4, 5], and on QCD factorization [6]. The latter incorporate light-cone distribution amplitudes evaluated from QCD sum rules. Expected branching fractions lie in the range  $5\text{--}10 \times 10^{-6}$  [6]; estimates as large as  $26 \times 10^{-6}$  are found in the calculations of [4], and  $40 \times 10^{-6}$  in those of [5].

The four modes  $B^+ \rightarrow b_1^0 \pi^+$ ,  $B^+ \rightarrow b_1^0 K^+$ ,  $B^0 \rightarrow b_1^\mp \pi^+$ , and  $B^0 \rightarrow b_1^\mp K^+$  can be mediated by external tree amplitudes in which the weak current produces the pion (kaon) with a Cabibbo-favored (suppressed) coupling. Alternatively, a “penguin” loop amplitude is favored for the kaon modes, and suppressed for the pion modes. The fifth mode,  $B^0 \rightarrow b_1^+ \pi^-$ , requires a coupling of the current to the  $b_1^+$ , which is forbidden for this  $G = +1$  state [7], leading to the expectation  $\mathcal{B}(B^0 \rightarrow b_1^+ \pi^-) \ll \mathcal{B}(B^0 \rightarrow b_1^\mp \pi^\pm)$ .

Direct  $CP$  violation would be indicated by a non-zero value of the asymmetry  $\mathcal{A}_{ch} \equiv (\Gamma^- - \Gamma^+)/(\Gamma^- + \Gamma^+)$  in the rates  $\Gamma^\pm(B^\pm \rightarrow F^\pm)$  for decay of a charged  $B$  meson, or  $\Gamma^+(B^0 \rightarrow b_1^\mp K^+)$  and its charge conjugate. For the decays  $B^0 \rightarrow b_1^\mp \pi^\pm$  we define  $\mathcal{A}_{ch}$  and two additional asymmetries  $C$  and  $\Delta C$  through

$$\Gamma_{q,f} = \frac{1}{4}(\Gamma + \bar{\Gamma})(1 + q\mathcal{A}_{ch})[1 + f(C + q\Delta C)], \quad (1)$$

where the signal  $B$  meson flavor  $f = +1$  for  $B^0$ ,  $-1$  for  $\bar{B}^0$ , and  $q$  is the sign of charge of the  $b_1$ . To measure  $C$  and  $\Delta C$  we use the flavor  $\eta$  ( $+1$  for  $B^0$  and  $-1$  for  $\bar{B}^0$ ) of the second meson  $B_{\text{tag}}$  produced in  $\Upsilon(4S)$  decay [8].

The yields are given by

$$Y_{q\eta} = \frac{1}{4}Y_S(1 + q\mathcal{A}_{ch}) \left\{ 1 - \eta\Delta w + \eta\mu(1 - 2w) - \eta(1 - 2\chi_d)[1 - 2w + \mu(\eta - \Delta w)](C + q\Delta C) \right\}, \quad (2)$$

where  $Y_S$  is the total signal yield,  $\chi_d = 0.188 \pm 0.003$  the time-integrated mixing probability [3],  $w$  the mistag fraction, and  $\Delta w$  and  $\mu$  the  $B - \bar{B}$  differences in the mistag rate and tagging efficiency, respectively.

The data were collected with the BABAR detector [9] at the PEP-II asymmetric  $e^+e^-$  collider located at the Stanford Linear Accelerator Center. Charged particles from the  $e^+e^-$  interactions are detected, and their momenta measured, by a combination of five layers of double-sided silicon microstrip detectors and a 40-layer drift chamber, both operating in the 1.5 T magnetic field of a superconducting solenoid. Photons and electrons are identified with a CsI(Tl) electromagnetic calorimeter (EMC). Further charged particle identification (PID) is provided by the average energy loss ( $dE/dx$ ) in the tracking devices and by an internally reflecting ring imaging Cherenkov detector (DIRC) covering the central region. A detailed Monte Carlo program (MC) is used to simulate the  $B$  production and decay sequences, and the detector response [10].

The  $b_1$  candidates are reconstructed through the decay sequence  $b_1 \rightarrow \omega \pi$ ,  $\omega \rightarrow \pi^+ \pi^- \pi^0$ , and  $\pi^0 \rightarrow \gamma \gamma$ . The invariant mass of the photon pair is required to lie between 120 and 150 MeV, i.e., within about two standard deviations of the nominal mass [3]. For the  $b_1$  and  $\omega$  whose masses are observables in the maximum likelihood (ML) fit described below, we accept a range that includes wider sidebands (see Fig. 1). Secondary charged pions in  $b_1$  and  $\omega$  candidates are rejected if classified as protons, kaons, or electrons by their DIRC,  $dE/dx$ , and EMC PID signatures. For the primary pion (kaon) from the  $B$ -meson decay we define the PID variable  $S_\pi$  ( $S_K$ ) as the number of standard deviations between the measured DIRC Cherenkov angle and that expected for a pion (kaon), requiring  $-2 < S_\pi < 5$  ( $-5 < S_K < 2$ ).

We reconstruct the  $B$ -meson candidate by combining the 4-momenta of a pair of daughter mesons, using a fit that constrains all particles to a common vertex and the  $\pi^0$  mass to its nominal value. From the kinematics of  $\Upsilon(4S)$  decay we determine the energy-substituted mass  $m_{\text{ES}} = \sqrt{\frac{1}{4}s - \mathbf{p}_B^2}$  and energy difference  $\Delta E =$

$E_B - \frac{1}{2}\sqrt{s}$ , where  $(E_B, \mathbf{p}_B)$  is the  $B$ -meson 4-momentum vector, and all values are expressed in the  $\Upsilon(4S)$  rest frame. The resolution in  $m_{\text{ES}}$  is  $2.4 - 2.7$  MeV and in  $\Delta E$  is  $25 - 32$  MeV, depending on the decay mode. We require  $5.25 \text{ GeV} < m_{\text{ES}} < 5.29 \text{ GeV}$  and  $-0.13 \text{ GeV} < \Delta E < \Delta E_{\text{max}}$ , with  $\Delta E_{\text{max}} = 0.1$  (0.13) GeV for  $b_1^0$  ( $b_1^+$ ), where the tighter restriction serves to limit the number of combinatorial candidates per event.

We also impose restrictions on resonance decay angles to exclude the most asymmetric decays where soft-particle backgrounds accumulate and the acceptance changes rapidly. We require  $\cos\theta_{b_1} \leq 1.1 - 0.5|\cos\theta_\omega|$ , where  $\theta_{b_1}$  is the angle between the momenta of the pion from  $b_1 \rightarrow \omega\pi$  and its parent  $B$  meson, measured in the  $b_1$  rest frame, and  $\theta_\omega$  is the angle between the normal to the  $\omega \rightarrow 3\pi$  decay plane and the momentum of its parent  $b_1$ , measured in the  $\omega$  rest frame. Backgrounds arise primarily from random combinations of particles in continuum  $e^+e^- \rightarrow q\bar{q}$  events ( $q = u, d, s, c$ ). We reduce these with a requirement on the angle  $\theta_T$  between the thrust axis of the  $B$  candidate in the  $\Upsilon(4S)$  frame and that of the rest of the charged tracks and neutral calorimeter clusters in the event. The distribution is sharply peaked near  $|\cos\theta_T| = 1$  for  $q\bar{q}$  jet pairs, and nearly uniform for  $B$ -meson decays. The requirement, which optimizes the expected signal yield relative to its background-dominated statistical error, is  $|\cos\theta_T| < 0.7$ . The average number of candidates found per selected event is in the range 1.3 to 1.4 (1.4 to 1.6 in signal MC), depending on the final state. We choose the candidate with  $\omega\pi$  invariant mass closest to the nominal value of the  $b_1$  mass [3]. In the ML fit we discriminate further against  $q\bar{q}$  background with a Fisher discriminant  $\mathcal{F}$  that combines several variables which characterize the energy flow in the event [11]. It provides about one standard deviation of separation between  $B$  decay events and  $q\bar{q}$  background.

We obtain yields for each channel from an extended ML fit with the input observables  $\Delta E$ ,  $m_{\text{ES}}$ ,  $\mathcal{F}$ , and the resonance masses  $m_{b_1}$  and  $m_\omega$ . The selected data sample sizes are given in Table I. Besides the signal events these samples contain  $q\bar{q}$  (dominant) and  $B\bar{B}$  with  $b \rightarrow c$  combinatorial background, and a fraction of cross feed from other charmless  $B\bar{B}$  modes, which we estimate from the simulation to be (0.5–0.8)%. The last include non-resonant  $\omega\pi(\pi, K)$ , and modes that have final states different from the signal, but with similar kinematics so that broad peaks near those of the signal appear in some observables, requiring a separate component in the probability density function (PDF). The likelihood function is

$$\mathcal{L} = \exp\left(-\sum_{j,q,\eta} Y_{j,q\eta}\right) \prod_i \sum_{j,q,\eta} Y_{j,q\eta} \times \quad (3)$$

$$\mathcal{P}_j(m_{\text{ES}}^i) \mathcal{P}_j(\mathcal{F}^i) \mathcal{P}_j(\Delta E^i) \mathcal{P}_j(m_{b_1}^i) \mathcal{P}_j(m_\omega^i),$$

where  $N$  is the number of events in the sample, and for

each component  $j$  (signal, combinatorial background, or charmless  $B\bar{B}$  cross feed),  $Y_{j,q\eta}$  is the yield of events (Eq. 2) and  $\mathcal{P}_j(x^i)$  the PDF for observable  $x$  in event  $i$ . The signal component is further separated into two components (with proportions fixed in the fit for each mode) representing the correctly and incorrectly reconstructed candidates in events with true signal, as determined with MC. The factored form of the PDF indicated in Eq. 3 is a good approximation, particularly for the combinatorial  $q\bar{q}$  component, since we find correlations among observables in the data (which are mostly  $q\bar{q}$  background) to be small. The effects of this approximation are determined in simulation and included in the bias corrections and systematic errors discussed below.

We determine the PDFs for the signal and  $B\bar{B}$  background components from fits to MC samples. We calibrate the resolutions in  $\Delta E$  and  $m_{\text{ES}}$  with large data control samples of  $B$  decays to charmed final states of similar topology (e.g.  $B \rightarrow D(K\pi\pi)\pi$ ). We develop PDFs for the combinatorial background with fits to the data from which the signal region ( $5.27 \text{ GeV} < m_{\text{ES}} < 5.29 \text{ GeV}$  and  $|\Delta E| < 0.1 \text{ GeV}$ ) has been excluded.

The functions  $\mathcal{P}_j$  are constructed as linear combinations of Gaussian and polynomial functions, or in the case of  $m_{\text{ES}}$  for  $q\bar{q}$  background the threshold function  $x\sqrt{1-x^2}\exp[-\xi(1-x^2)]$ , with argument  $x \equiv 2m_{\text{ES}}/\sqrt{s}$  and parameter  $\xi$ . These functions are discussed in more detail in [11], and are illustrated in Fig. 1.

We allow the parameters most important for the determination of the combinatorial background PDFs to vary in the fit, along with the yields for all components, and the signal and  $q\bar{q}$  background asymmetries. Specifically, the free background parameters are:  $\xi$  for  $m_{\text{ES}}$ , linear and quadratic coefficients for  $\Delta E$ , and the mean, width, and width difference and polynomial fraction parameters for  $\mathcal{F}$ .

We validate the fitting procedure by applying it to ensembles of simulated experiments with the  $q\bar{q}$  component drawn from the PDF, into which we have embedded the expected number of signal and  $B\bar{B}$  background events randomly extracted from the fully simulated MC samples. Biases obtained by this procedure with inputs that reproduce the yields found in the data are reported, along with the signal yields, in Table I.

In Fig. 1 we show the projections of the PDF and data for each fit. The data plotted are subsamples enriched in signal with a threshold requirement on the ratio of signal to total likelihood (computed without the plotted variable) that retains (29–53)% of the signal, depending on the mode.

We compute the branching fraction by subtracting the fit bias from the measured yield, and dividing the result by the efficiency times  $\mathcal{B}(\omega \rightarrow \pi^+\pi^-\pi^0) = 89.1 \pm 0.7\%$  [3], and by the number of produced  $B\bar{B}$  pairs. We assume  $\Gamma(\Upsilon(4S) \rightarrow B^+B^-)/\Gamma(\Upsilon(4S) \rightarrow B^0\bar{B}^0) = 1$ , consistent with measurements [3]. The results are given in Table I,

TABLE I: Number of events  $N$  in the sample, fitted signal yield  $Y_S$ , and measured bias (to be subtracted from  $Y_S$ ) in events (ev.), detection efficiency  $\epsilon$ , significance  $\mathcal{S}$  (with systematic uncertainties included), and branching fraction and charge asymmetry with statistical and systematic error.

Mode	$N$ (ev.)	$Y_S$ (ev.)	Bias (ev.)	$\epsilon$ (%)	$\mathcal{S}$ ( $\sigma$ )	$\mathcal{B}$ ( $10^{-6}$ )	$\mathcal{A}_{ch}$
$b_1^0 \pi^+$	32176	$178^{+39}_{-37}$	$26 \pm 14$	6.78	4.0	$6.7 \pm 1.7 \pm 1.0$	$0.05 \pm 0.16 \pm 0.02$
$b_1^0 K^+$	18036	$219^{+38}_{-36}$	$24 \pm 12$	6.73	5.3	$9.1 \pm 1.7 \pm 1.0$	$-0.46 \pm 0.20 \pm 0.02$
$b_1^\mp \pi^\pm$	36901	$387^{+41}_{-39}$	$34 \pm 17$	9.54	8.9	$10.9 \pm 1.2 \pm 0.9$	$-0.05 \pm 0.10 \pm 0.02$
$b_1^- K^+$	17497	$267^{+33}_{-32}$	$32 \pm 16$	9.43	6.1	$7.4 \pm 1.0 \pm 1.0$	$-0.07 \pm 0.12 \pm 0.02$

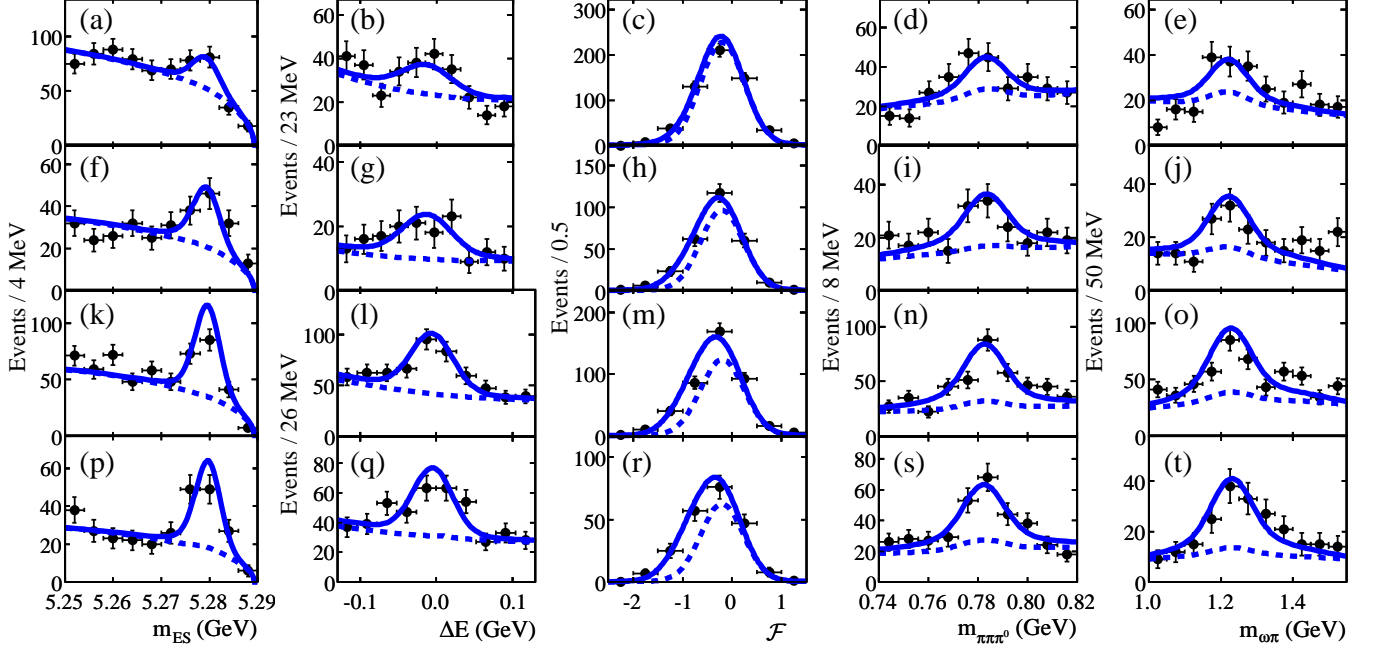


FIG. 1: Distributions for signal-enhanced subsets of the data projected onto the fit observables for the decays: (a-e)  $B^+ \rightarrow b_1^0 \pi^+$ , (f-j)  $B^+ \rightarrow b_1^0 K^+$ , (k-o)  $B^0 \rightarrow b_1^\mp \pi^\pm$ , and (p-t)  $B^0 \rightarrow b_1^- K^+$ . The solid line represents the result of the fit, and the dashed line the background contribution.

along with the significance, computed as the square root of the difference between the value of  $-2 \ln \mathcal{L}$  (with additive systematic uncertainties included) for zero signal and the value at its minimum.

Systematic uncertainties on the branching fractions arise from the PDFs,  $B\bar{B}$  backgrounds, fit bias, and efficiency. PDF uncertainties not already accounted for by free parameters in the fit are estimated from the consistency of fits to MC and data in control modes. Varying the signal-PDF parameters within these errors, we estimate yield uncertainties of (2.4–3.3)%, depending on the mode. The uncertainty from fit bias (Table I) includes its statistical uncertainty from the simulated experiments, and half of the correction itself, added in quadrature. For the  $B\bar{B}$  backgrounds we vary the fixed fit component by 100% and include in quadrature a term derived from MC studies of the inclusion of a  $b \rightarrow c$  component with the dominant  $q\bar{q}$  background. Uncertainties in our knowledge of the efficiency include  $0.5\% \times N_t$  and  $1.5\% \times N_\gamma$ , where

$N_t$  and  $N_\gamma$  are the numbers of tracks and photons, respectively, in the  $B$  candidate. The uncertainties in the efficiency from the event selection are below 0.5%.

We study asymmetries from the track reconstruction (found negligible), and from imperfect modeling of the interactions with material in the detector, by measuring the asymmetries in the  $q\bar{q}$  background in the data and control samples mentioned previously, in comparison with MC [12]. We apply corrections, and assign systematic errors, to  $\mathcal{A}_{ch}$  equal to  $-0.010 \pm 0.005$  for modes with a primary kaon and  $0.000 \pm 0.005$  for those with a primary pion. The leading systematic errors on  $C$  and  $\Delta C$  come from the fit bias.

With the assumption that  $\mathcal{B}(b_1 \rightarrow \omega \pi) = 1$ , we obtain for the branching fractions:

$$\begin{aligned}
 \mathcal{B}(B^+ \rightarrow b_1^0 \pi^+) &= (6.7 \pm 1.7 \pm 1.0) \times 10^{-6} \\
 \mathcal{B}(B^+ \rightarrow b_1^0 K^+) &= (9.1 \pm 1.7 \pm 1.0) \times 10^{-6} \\
 \mathcal{B}(B^0 \rightarrow b_1^\mp \pi^\pm) &= (10.9 \pm 1.2 \pm 0.9) \times 10^{-6} \\
 \mathcal{B}(B^0 \rightarrow b_1^- K^+) &= (7.4 \pm 1.0 \pm 1.0) \times 10^{-6}.
 \end{aligned}$$

For the asymmetries we find

$$\begin{aligned}
\mathcal{A}_{ch}(B^+ \rightarrow b_1^0 \pi^+) &= 0.05 \pm 0.16 \pm 0.02 \\
\mathcal{A}_{ch}(B^+ \rightarrow b_1^0 K^+) &= -0.46 \pm 0.20 \pm 0.02 \\
\mathcal{A}_{ch}(B^0 \rightarrow b_1^\mp \pi^\pm) &= -0.05 \pm 0.10 \pm 0.02 \\
C(B^0 \rightarrow b_1^\mp \pi^\pm) &= -0.22 \pm 0.23 \pm 0.05 \\
\Delta C(B^0 \rightarrow b_1^\mp \pi^\pm) &= -1.04 \pm 0.23 \pm 0.08 \\
\mathcal{A}_{ch}(B^0 \rightarrow b_1^- K^+) &= -0.07 \pm 0.12 \pm 0.02.
\end{aligned}$$

The first error quoted is statistical and the second systematic. The QCD factorization estimates [6] for the branching fractions and charge asymmetries agree with these measurements within experimental and theoretical errors. The authors of [6] note that the observation  $\mathcal{B}(B^+ \rightarrow b_1^0 K^+)/\mathcal{B}(B^0 \rightarrow b_1^- K^+) > 0.5$ , if confirmed with higher precision, would indicate the presence of a weak annihilation contribution to these modes. The value of the  $CP$ -conserving  $\Delta C$  near  $-1$  for  $B^0 \rightarrow b_1^\mp \pi^\pm$  agrees with the expected suppression of  $B^0 \rightarrow b_1^+ \pi^-$ ; our results imply the ratio  $\Gamma(B^0 \rightarrow b_1^+ \pi^-)/\Gamma(B^0 \rightarrow b_1^\mp \pi^\pm) = -0.01 \pm 0.12$ . We find no evidence for direct  $CP$  violation in these decays.

We are grateful for the excellent luminosity and machine conditions provided by our PEP-II colleagues, and for the substantial dedicated effort from the computing organizations that support *BABAR*. The collaborating institutions wish to thank SLAC for its support and kind hospitality. This work is supported by DOE and NSF (USA), NSERC (Canada), CEA and CNRS-IN2P3 (France), BMBF and DFG (Germany), INFN (Italy), FOM (The Netherlands), NFR (Norway), MES (Russia), MEC (Spain), and STFC (United Kingdom). Individuals have received support from the Marie Curie EIF (Euro-

pean Union) and the A. P. Sloan Foundation.

---

\* Deceased

† Now at Tel Aviv University, Tel Aviv, 69978, Israel

‡ Also with Università di Perugia, Dipartimento di Fisica, Perugia, Italy

§ Also with Università della Basilicata, Potenza, Italy

¶ Also with Universitat de Barcelona, Facultat de Fisica, Departament ECM, E-08028 Barcelona, Spain

- [1] *BABAR* Collaboration: B. Aubert *et al.*, Phys. Rev. Lett. **97**, 051802 (2006).
- [2] Charge-conjugate reactions are implied unless noted.
- [3] Particle Data Group: Y.-M. Yao *et al.*, J. Phys. **G33**, 1 (2006) and 2007 partial update for the 2008 edition.
- [4] V. Laporta, G. Nardulli, and T. N. Pham, Phys. Rev. D **74**, 054035 (2006); hep-ph/0602243v4 (erratum to appear in Phys. Rev. D).
- [5] G. Calderon, J. H. Munoz, and C. E. Vera, arXiv:0705.1181v2 (2007).
- [6] H.-Y. Cheng and K.-C. Yang, arXiv:0709.0137v1 (2007).
- [7] S. Weinberg, Phys. Rev. **112**, 1375 (1958).
- [8] *BABAR* Collaboration: B. Aubert *et al.*, hep-ex/0703021 (2007); Phys. Rev. Lett. **94**, 161803 (2005).
- [9] *BABAR* Collaboration: B. Aubert *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **479**, 1 (2002).
- [10] The *BABAR* detector Monte Carlo simulation is based on GEANT4: S. Agostinelli *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **506**, 250 (2003).
- [11] *BABAR* Collaboration: B. Aubert *et al.*, Phys. Rev. D **70**, 032006 (2004).
- [12] *BABAR* Collaboration: B. Aubert *et al.*, Phys. Rev. Lett. **99**, 021603 (2007).